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BY

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ON THE RADIO AND X-RAY EMISSION OF SOLAR FLARES

by A. K. Pankratov

27199

Data on f_{min} radio emission and solar flares, collected during the IGY and IGC by observatories and stations have been used.

The connection between X-ray emission and the emission in H_α of flares is studied statistically.

Six intense chromospheric flares (importance 3 and 3+), which were not accompanied by X-ray emission ($\lambda \leqslant 8$ Å), were detected and also eight "doubled" flares which generated X-ray emission only in one knot or maximum.

The absence of a directivity effect in the X-ray emission of flares is established.

It is found that all type IV bursts of radio emission are accompanied by an appreciable flow of X-ray emission, sufficient for the appearance of a well noticeable (according to f_{min}) additional ionization of the D layer. The possibility of a unique relation between the presence of X-ray emission of solar flares and type IV bursts of radio emission is discussed briefly.

It is proved that several intense ionospheric effects (in the D layer) are due to the X-ray emission from behind-the-limb flares, which are seen from the earth as a subflares or not at all. An identical result was obtained in [11] and [12]. This fact is apparently evidence that the region of generation of X-ray emission is not limited by the region of flare emission in H_α but extends to heights of several tens of thousands of kilometers into the region of coronal condensations.

Author

By increasing the ionization in the lower ionosphere [1], the X-ray emission produces a large number of geophysical effects, such as the sudden increase in the absorption of cosmic noises (SCNA), the absorption of radio shortwaves (SWF), the growing minimum reflection frequency per f_{min}, etc.

An investigation into these phenomena would make a considerable contribution to the understanding of the nature of the physical processes in the flares.

Making use of the vast experimental material accumulated all over the world during IGY-IGC, it would be possible to attempt a solution of such important problems in the physical aspect of flares as the nature, height

[redacted]nd

of generation and hardness of X-ray emission, its interrelation with the development of flares in H_α as well as the radio emission of flares and the acceleration of protons to high energies, etc.

We will examine some of these problems in this article.

I. Observation Data

The following data were used in the investigation: on chromospheric flares and brightness [2-5], surges and active prominences [6], radio emission of solar flares [7, 8], and in some cases also the data on SWF [4].

Solar x-ray emission was studied by the increasing minimum reflection frequencies of f_{min} revealed by a vertical probe of the ionosphere. The observation results obtained by the world network of ionospheric station during the IGY-IGC period were used for that purpose.

Three groups of closely arranged stations with 15-minute intervals between the observations and homogeneous observation results were used as base stations.

a) Peru stations: Huancajo (12S 75.3W), Talara (4.6S 81.2W) and Chimboto (9S 78.6W) -- active observation of flares from 13 through 22^h universal time.

b) Japanese stations: Akite (39.7N 140.1E), Kokubunji (35.7N 139.5E), Wakkanai (45.4N 141.7E), Yamagawa (31.2N 130.6E) and Okinawa (26.5N 128.0E) -- active observation of flares from 23 to 7^h universal time.

c) Soviet stations: Simferopol' (34.1E 44.7N), Moscow (55.5N 37.3E) and Gor'kiy (56.2N 44.3E) -- effective observation of flares from 5 through 14^h universal time.

The phenomenon was included in the list of X-ray effect if the growing f_{min} was clearly prominent against the background of the diurnal course, and its beginning, duration and amplitude coincided well with those at the neighboring stations. The first observation, when the rise became noticeable,

was considered as the initial effect, and the last observation prior to the disappearance of that rise was considered as the end effect. The origin of the effect coincides, within 15 minutes, with the occurrence of an X-ray radiation flux which is adequate for an observable additional ionization in the D layer. The end of the effect was in many cases determined less accurately as the f_{min} return to a quiescent level was frequently very gradual.

A total of about 600 X-ray effect were thus singled out, on the basis of f_{min}, during the IGY-IGC period. Each case was characterized by a point on a three-point scale that took into account the amplitude and duration of the effect as well as the zenith angle of the sun. All the effects occurring in the interval of $13\text{-}22^h$ UT [universal time] were very carefully singled out. A certain number of mild effects in the $23\text{-}7^h$ UT interval could be omitted due to the considerable fluctuation of the f_{min} at the Japanese stations. In view of the wide geographic latitude ($\geqslant 45^\circ$N), the soviet stations were less sensitive to the effects of the flares in winter time. There was no information for November-December 1959 from the Peru stations. On the whole, however, the list of the flare effects turned out to be fairly long, and was used for making further comparisons.

II. Comparing the Effects of X-ray Emission with Chromospheric Flashes

1. Corresponding chromospheric flashes were found for 79% of the (600) X-ray effects. In 9% of the effects there was more than one flash (2-3) for each effect, and no unique relation was established. The other 12% of the effects will be discussed below (see section IV).

2. Flashes with X-ray emission were found to be almost uniformly distributed in all the longitudes from the central solar meridian, and in the latitude belt approximately $\pm 30^\circ$ from the equator. It should be pointed

out, however, that a sharp disparity in the number of X-ray effects between the northern and southern hemispheres of the Sun was noted in 1959. Only 14 of the 150 effects, that is $\sim$ 10%, were produced by southern flares.

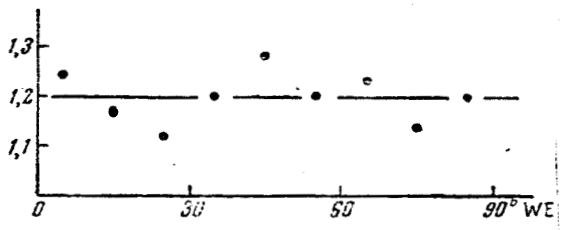

Fig. 1. The dependence of the average point of X-ray effect (according to f_{min}) on the longitude of the corresponding flare.

All the X-ray effects identified with the flashes were then checked to see if there was any directivity effect in the intensity of the X-ray emission. Had such an effect been discovered, it would have meant that a considerable share of the X-ray flux was regenerated at a depth of 50 km in the photosphere; that is at a depth of over 0.3 gram [9]. To that end, the scale points of the X-ray effects were averaged up within each longitude range from the central solar meridian (0-10°, 10-20°, ...). The results of the averaging process are cited in Fig. 1 where the distance from the central meridian, expressed in degrees, is plotted on the X-axis, and the averaged point of the X-ray effect on the Y-axis. Each point corresponds to more than 45 cases of X-ray emission. The figure shows that all the points can be easily arranged on a horizontal straight line, and that there is apparently no tangible directivity effect. Thus the major share of the X-ray flux is regenerated at depths of less than 50 km in the photosphere or in the chromosphere.

3. In view of the long time interval between the ionospheric observations (15 min), our information was of little use for a detailed study of the temporary correspondence between the X-ray emission and the glow in H_α. In a number of cases, however, we tried to do it by statistical methods.

Fig. 2 shows the distribution of the time of the occurrence of the

glow in H_α (curve I) and the X-ray effects in the D layer (curve II) in relation to the maximum flare in H_α. Used in this connection were 72% of the X-ray effects for which the maximum flash moments are given in [2, 5]. Plotted on the X-axis is the time lag of the corresponding effect in relation to the maximum flare in H_α, and on the Y-axis the number of cases with a particular time lag. Distribution II shows that the largest number of initial X-ray effects fit into a $\pm$ 15-minute time interval from the maximum flare in H_α, and the maximum distribution is displaced $\sim$ 5 minutes to the right of the origin of the coordinates.

Due to the long time interval between the successive observations (15 minutes), the discovery of the X-ray emission by the f_m was delayed an average of 5-7 min. from the occurrence of an X-ray flux adequate to produce an observable additional ionization in the D layer. If we take this into account, the II distribution will be shifted 5-7 minutes to the left. In that case the occurrences of the corresponding X-ray flux will be very close to the maximum flare moments in H_α.

Distribution II was divided according to the duration of the X-ray emission into five parts which are shown in Fig. 3 in the same coordinate axes. The figure in each distribution indicates the number of 15-minute observation intervals with an increased f_{min}. The figure shows that the shorter the X-ray effect, the closer its occurrence to the maximum flare, and, by the same token, the longer (and more powerful) the effect, the earlier than the maximum flare it will occur. It is clear from Fig. 3 that the left wing of distribution II is made up primarily of very durable effects. We should point out that Fig. 2 does not include the extreme left part of distribution II. It can be clearly seen when the distributions in Fig. 3 are added up.

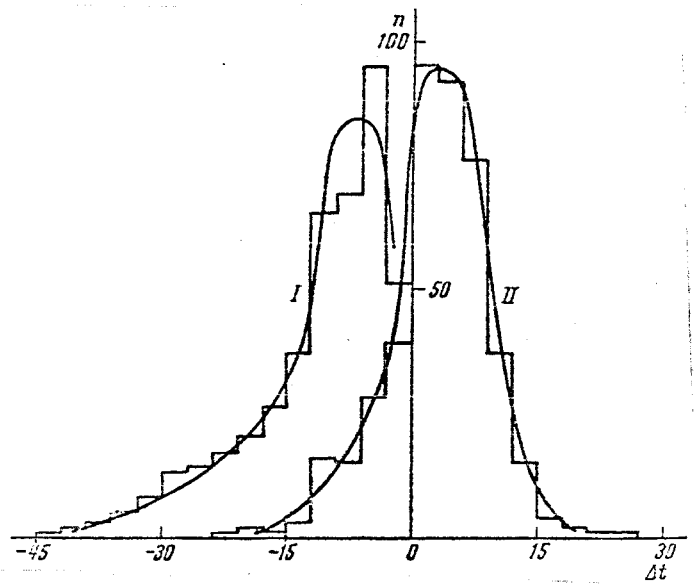

Fig. 2. The time lag distribution of the initial discoveries of the X-ray emission by f_{min} in relation to the maximum flare in H_α, that is the distribution.

$\Delta t = t_{init.\ X} - t_{max\ H_\alpha}$ (curve II) and $\Delta t = t_{init.\ H_\alpha} - t_{max\ H_\alpha}$ (curve I)

4. Distribution II in Fig. 2 is displaced in relation to distribution I by $\sim$ 11 minutes. The distribution of the initial flares in H_α in relation to the moments of the discovery of the X-ray emission is shown more graphically in Fig. 4. Taking the 5-7 min. correction into consideration again, we find that the time lag of the corresponding X-ray flux in relation to the initial flare averaged about 5 min. for the entire distribution. Thus at the very beginning of the flare the X-ray emission is either insufficiently intense or hard to produce an observable additional ionization in layer D.

5. The conclusion [1] that the glow of the flash in H_α usually lasts longer than the X-ray emission is supported by a larger mass of information.

In addition to the flares cited in [1], another flash was found on 30 July 1958 at 15^h23^m in which the duration of the X-ray emission was considerably longer than that of a flare in H_α. There is also a number of similar

cases of flashes on a limb (for example, No. 0023, 1296 and 1716, according to [5]) where the actual duration of the glow in H_α could considerably exceed the observable duration.

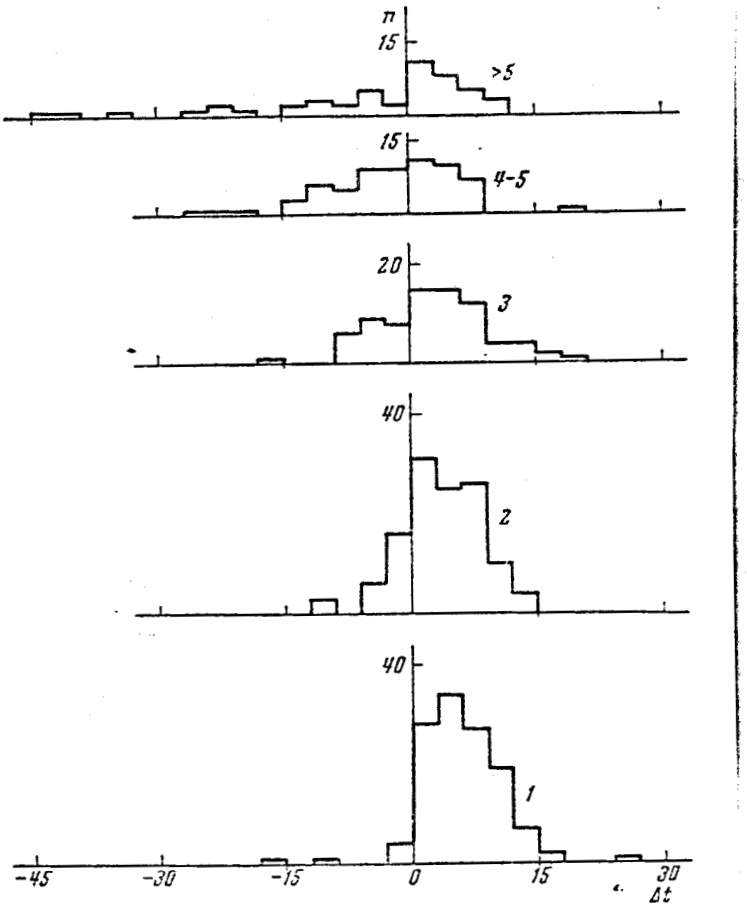

Fig. 3. Distribution II from Fig. 2 divided into five parts in accordance with the duration of the X-ray effect on the basis of f_{min}.

Six very strong flashes were found (points 3 and 3+) were found which were not accompanied by X-ray emission (No. 2066, 2945, 5627, according to [2], and No. 0216, 0300, 1357, according to [5]), and this result is confirmed by the information on the fading radio shortwaves (SWF).

Of considerable interest from the point of view of high-energy electron generation in the flare are the "doubled" flares (see [2, 5]) which have either a double-humped development curve in H_α or two close conflagrant points of the same strength. We have found eight such "doubled" flares with

a generation of X-rays in only one point [10] or in a maximum (No. 1074, 1121, 0843, 2168, 5910, according to [2] with a generation of X-rays only in the second point or the maximum, and No. 1810, 2275 according to [2] and No. 2673 according to [5] with a generation of X-rays only in the first point or maximum).

We have also found 11 "doubled" flares with a generation of X-5ays in both points or maximums (No. 0055, 0710, 0849, 1067, 1068, 1571, 1841, 2124, 4130, 4140, 5569, according to [2]). These results of the "doubled" flares are confirmed by the data on SWF. All these cases require a further study with the use of the information on the configuration of the magnetic fields in the flare, the development curves of the flare in H_α and other data.

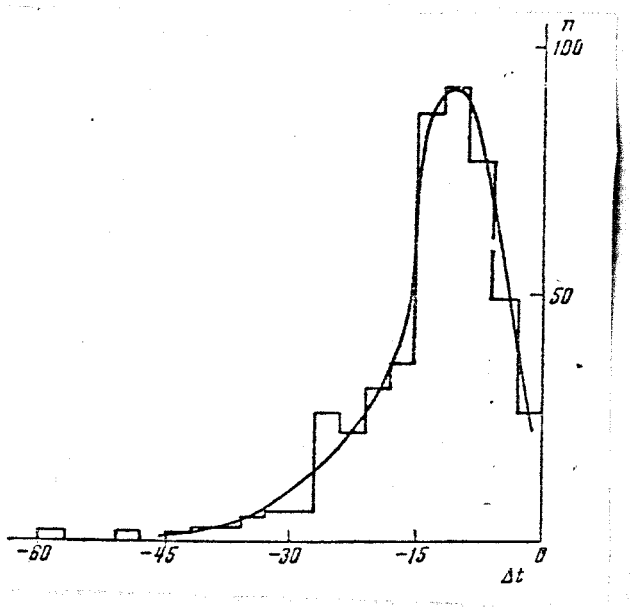

Fig. 4. The distribution of the X-ray time lags by f_{min} in relation to the initial flare in H_α, that is $\Delta t = t_{init.\ x} - t_{init.H_\alpha}$

III. Comparing the effect of X-ray emission with the radio emission of the flares

1. We had information of 56 type IV flash-ups [7] of which 42 occurred during the IGY-IGC period under study. All of them were accompanied by a considerable increase in the minimum reflection frequencies. We also had

SWF data [4] on six more flash-ups in June 1957, and two in March 1960. All the eight flash-ups were accompanied by considerable effects in SWF.

2. Twenty of the 42 type IV flash-ups had only the first phase (category A) on the meter waves, and 22 flash-ups had the first and second phases (category B) [7]. It was found that the category B flash-ups were accompanied on the average by larger fluxes of X-ray emission than the category A flash-ups. Indeed, in 20 category A cases, the average scale-point of the X-ray effect in f_{min} was 2.0, and in 22 category B cases it was 2.4. Although the flares corresponding to 80% of the category A flash-ups are found in the longitude belt of 45-90° from the central meridian, and those corresponding to 74% of category B flash-ups in the belt of 0-45° from the central meridian [7], it is obvious that the above-mentioned result cannot be explained by such a longitudinal distribution of radiation sources (see Section II, para 2), and it is apparently connected with the other characteristics of these sources.

3. According to [7], the flash-ups of radio-frequency emission on a 10 cm wave with a duration of over 10 min. and a maximum flux density of more than 200.10^{-22} watt/m^2 • cps are accompanied with a high degree of probability (90%) by flash-ups of type IV radio-frequency emission. One hundred, or 90% of the 111 such flash-ups, taken from [7], are accompanied by a definite rise of f_{min}. When the information on SWF was included, that share went up to 95%, that is in such flash-ups the probabilities of being accompanied by X-ray emissions and type IV flash-ups were very close to one another. The mentioned Pick-Gutmann criterion [7] is thus confirmed.

On the other hand, the conclusion made in point 1 of the third section to the effect that all the type IV flash-ups are accompanied by a considerable flux of X-ray emission is well confirmed. It should be pointed out that the remaining 5% of the strong flash-ups on a 10-cm wave are not

accompanied by X-ray emission 26 Sept 1957 at 18:36; 19 Dec 1957 at 09:16; 12 Feb 1958 at 23:42; 14 Jan 1959 at 21:30; 21 Dec 1959 at 00:50).

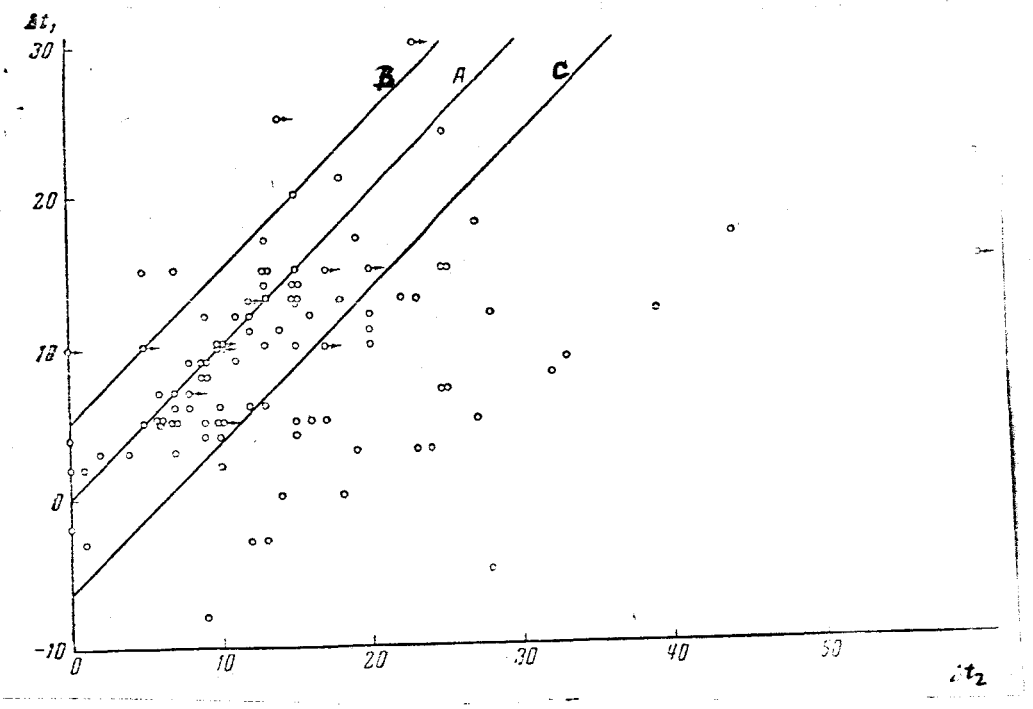

Fig. 5. Distribution $\Delta t_1 = t_{init.X} - t_{init.\ 10\ cm}$ in relation to $\Delta t_2 = t_{init.X} - t_{init.\ H_\alpha}$

4. The information on type IV flash-ups at our disposal (from [7] and [8]) applied to only 130 of the 600 X-ray effects under consideration layer D. Are the remaining X-ray effects accompanied by type IV flash-ups? We have not discussed that problem, but assume that they are. This may be gleaned from the following.

According to [7], about 25% of the flash-ups on a 10-cm wave with a duration of less than 10 min. and a maximum flux density of over $100 \cdot 10^{-22}$ wt/m^2 · cps, as well as about 50% of the flash-ups on a 10-cm wave with a duration of over 10 minutes and maximum flux density of $(50 + 100) \cdot 10^{-22}$ wt/m^2 · cps are accompanied by type IV flash-ups on meter waves. Inasmuch as the number of such flash-ups exceeds the number of flash-ups with a duration of over 10 minutes and a maximum flux density over $200 \cdot 10^{-22}$ wt/m^2 ·

cps, it is quite possible that the other 470 X-ray effects also include type IV flash-ups. This problem will be dealt with in a separate work.

5. The conclusion made in [1] to the effect that the beginning of X-ray production is considerably closer to the initial radio emission on centimeter waves (10 cm) than to the initial flare in H_α is confirmed by voluminous source materials. This may be gleaned from Fig. 5 where the time lag of the initially discovered X-ray effect in relation to the initial flare is plotted on the X-axis, and the same is plotted on the Y-axis in relation to the initial radio emission on a 10 cm wave. Individual cases are indicated by circles. The arrows to the right show that the flare began before the time indicated in [2] and [5], and that these circles should be shifted to the right.

A total of 103 X-ray effects with a type IV radio emission from [7] and [8] and a single-valued chromospheric flare are represented in the figure. The latter shows that in the majority of cases the initial X-ray and radio emissions coincide within 15 minutes, which is the time interval between two successive ionospheric observations. Only about 10% of the cases extend beyond that interval. It is possible in such cases that there was an X-ray emission at the time of the previous observations but it was too weak to produce a noticeable increase in f_{min}, whereas a more sensitive ground apparatus already discovered an initial radio flash-up.

In the case of an ideal coincidence of the initial X-ray emission, radio emission on a 10-cm wave and a glow in $H_\alpha$all these cases could be represented on a diagonal straight line A. Actually, bearing in mind the possible errors in determining the beginning of the flare and radio emission, the cases found between the B and C straight lines may be assumed to be well coinciding. About 30% of the cases are to the right of the straight

line C. In these cases the initial X-ray emission is considerably closer to the initial radio emission than to the initial flare.

In view of the above statement, it is obviously safe to assert that the X-ray (f_{min}) and radio emission on a 10-cm wave begin to be generated almost simultaneously.

IV. X-ray emission from limb and trans-limb flares

1. Here we will discuss the remaining 12% of the effects, that is the 71 cases mentioned in section II, para. 1.

In 15 cases there was no flare patrol, according to [3] and [4].

In 10 cases the brightnesses on the disc coincided in time, but we will not discuss the reliability of these identifications here.

In 8 cases (No. 6, 7, 8, 13, 22, 23, 24 and 25 in the table below), brilliancies or short flashes were found on the limb as well as corresponding bright surges on the limb.

In two cases (No. 3, 12) there were brilliancies on the limb and corresponding active prominences.

In five cases (No. 4, 11, 18, 19, 21) there were only surges on the limb.

In seven cases (No. 1, 2, 14, 15, 16, 17, 20) there were only active prominences; and in two cases (No. 9, 10) the X-ray effect could be associated with the brightness or an independent surge.

No optical indication of activity were found in the remaining 22 cases, although there was a flare patrol (a partial one).

The optical effects of these 22 events could have been omitted because of the incomplete data on the brilliancies, surges and active prominences. We will not discuss these events here.

The following information is cited in the table (by column):

1) the ordinal number of the effect;

2) the date of the effect;

3) the beginning and end of the X-ray effect in f_{min};

4) approximate scale-point of the X-ray effect in f_{min};

5) optical manifestations of activity: type of activity, scale-point (strength), time interval of activity, coordinates, description and station reporting these data;

6) number of the flocculent region, according to the International Astronomical Committee of the International Astronomical Association [2, 5], with which the optical phenomenon is associated;

7) The longitude range of the part of the region during the given X-ray effect where the centers of the flares occurring in the nearest quarter revolution of the Sun are found; in a number of cases the supposed longitude of the phenomenon is more accurately indicated;

8) the number of X-ray flashes (not counting the event under discussion) found by the f_{min} found in given active region during its next passage across the solar disc; in 30% of these flares we had information on type IV flash-ups, but the Table indicates that information for only two cases (No. 3, 10).

The ninth column will be explained later.

2. The trans-limb [Russian term: zalimbovaya] cannot be seen from the Earth if its edge nearest to us is at $\sim 10^{\circ}$ longitude beyond the edge of the disc, and the height of the flare is 10,000 kilometers above the photosphere.

The table shows that in the events revealing a surge or active prominence, the corresponding active region is on the average located farther from the central meridian than in the events characterized by a brilliancy

or short flashes, and the condition of invisibility is apparently fulfilled. And even in these cases of brilliancies and flashes on the limb, the centers of the active regions are located at longitudes more than 90° from the central meridian.

It is possible to visualize a series of successive events at ever-increasing distances from the central meridian:

a) a usual flare on the limb and corresponding surges and active prominences;

b) a very short flash on the limb, as compared to an X-ray effect, and corresponding surges and active prominences;

c) brilliance on the limb, possibly representing the upper or nearest end to us of a trans-limb flare, invisible from the Earth, and corresponding surges and active prominences;

d) only surges and active prominences.

The information cited in the table shows that in six of the events (No. 3, 5, 7, 8, 11, 23), the identification of the X-ray effect with the optical manifestation of the activity is apparently beyond doubt. The identifications in the events No. 6, 15, 16, 18, 19 are also fairly reliable.

Thus there is apparently no doubt about a considerable X-ray flux ($\lambda \leqslant 8\text{Å}$) being emitted by far-away limb and trans-limb flares.

The events of 9 June 1959 and 2 August 1958, associated with the most powerful fluxes of X-ray emission, deserve particular attention. In the former case, there was not even an increase in the brightness during the first half hour or so, even though a powerful X-ray flux had already been recorded on the Earth. Corresponding to that event was a considerable flux of high-energy protons in the polar cap. The rising f_{min} above the steady-state level at the Resolute station (74.7 N 94.9 W) amounted to 1-3

megacycles, and continued from 10 through 19 June. There was also a mild magnetic storm which broke out suddenly at about noon on 11 June 1959. The condition for the propagation of high-energy protons from the eastern limb were apparently fairly favorable, as there had been only one unidentified medium-intensity storm throughout the preceding revolution of the Sun, and the field had been almost still during the previous half turn (see [11, 12]).

The X-ray emission on 2 August 1958 was also powerful and lasting, but in that case no flares or brightness were observed during the entire X-ray effect. Both events were accompanied by flashes of type IV radio emission.

3. From the trans-limb flares, visible from the Earth only as bright spots, the X-ray can reach the Earth if it originates at the level of the flare luminescence in H_α or higher, and from flares invisible from the Earth it can reach it from still greater heights. The powerful X-ray flux coming from such flares indicates that a considerable portion of it is generated above the region of the flare luminescence in H_α.

In column 9 of the table we indicated the lowest altitude above the photosphere still visible from the Earth for the far side of the active region where the nearest quarter revolution of the Sun was characterized by flares (of greater magnitude). The smaller magnitude is the altitude of the flare above the photosphere which we assumed to be $\sim$ 10,000 kilometers.

Judging from the magnitudes listed in column 9, the lowest point opposite the center of the flare still visible from the Earth will have an altitude of $\sim$ 10,000-30,000 kilometers above the photosphere. And the region where the X-ray reaching the earth is generated will be still higher, extending into the region of coronal condensation.

Worthy of particular attention in this connection are the cases mentioned in section two when the duration of the X-ray emission was considerably longer than the duration of the flare in H_α, even though the

longitudes of those flares were less than 80° from the central meridian, and the end of the flare was apparently determined fairly accurately.

It is possible that in these cases, after the end of the flare glow in H_α, the X-ray emission originated primarily above the region of the flare that glowed in H_α. In at least two such cases (31 August 1957 and 26 August 1958) it is known that the type IV flash-ups associated with them were exceptionally long-lasting [7]. That means that the region immediately above the flare was still highly active for a very long time after the flare had ceased to glow in H_α.

A detailed discussion of the dynamics of limb flares appears in [13, 14]. According to [13, 14], the altitude of the flare may be as high as 50,000 kilometers above the photosphere, and the picture of the development of such a flare is in general similar to that of an isolated surge. Such a flare differs from a surge primarily by greater brilliance and compactness and the presence of a conflagration phase at the beginning of the flare.

It is possible that the number of surges cited in the table represent just that type of flares, but insufficient information prevents us from stating that fact with certainty.

In conclusion, I express my gratitude to A. S. Dvoryashin, N. N. Yerushev and B. M. Vladimirskiy for their valuable comments.

14 May 1962

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Note in proofreading. The catalog of flares published in May 1962 (IGY Solar Activity Report Series, No. 17, 1962) for the events listed in the table of this article, mentions a number of brilliances not included in the article, particularly the event of 2 August 1958. This will produce a minor change in the distribution of the events by category, as listed in the very beginning of para. 4, which is not essential. Further, the identification of the event of 25 October 1957 with a limb flare is apparently doubtful, as the flare was of scale-point 1 strength, 18:55 - 19:28 N 26 W 50.

No.	Date	Begin. & end of X-ray effect	Strength of X-ray	Optical manifestations of activity	No. of region, per Mac Mas	Longitude of region	Number of X-ray flares	Minimum height in units of 10^3 km*
1	1.VII.1957	17:15-17:30	1 -	Active prominence (point 1) 17:57-18:02, N00 W90, no related flare observable; fluxes moving to +5° and -8° latitude [Edinburgh]	?			
2	15.VII	20:30-22:00	2 -	Active prominence (point 2) 21:10-00:03, position angle 115°, average activity [Sacramento Peak]	?			
3	20.VII	17:45-19:00	2	Brilliance, 18:06 E, S32 W90 [Sacramento Peak]) Active prominence (point 3) 18:06-22:00, position angle 236°, high activity, developed from point 1 flare - [Sacramento Peak])	4061	79-89 W	1 (type IV flash-up)	~10
4	9.VIII	14:30-16:30	1 +	Surge (point 1) 14:36-14:42, S35 W90, height 0.03R [Mount Wilson]	4082	90-114 W	1	~10-66
5	7.IX 1957	00:45-03:00	1 +	Flare (point 1) 00:45-00:50, S28 W90 [Mount Wilson]	4125	88-106 W	4	~10-28 (after the flare)
6	24.X	14:30-17:00	2 -	Flare (point 1) 16:26 E-16:32, S29) W90 [Mount Wilson]) Surge (point 3) 16:20-19:00, position angle 238°, connected with point 1 flare; large, very bright [Sacramento Peak])	4189	79-102 W ~ 95 W	12	~10-15 (before and after the flare)

*The estimate of the altitude in this column did not take into account the inclination of the solar equator plane to that of the ecliptic. This circumstance would increase the altitude of the far side of the active regions in almost all of the events.

7	25.X	18:45-19:30	2	Surge (point 2) 18:30-$>$19:00, position angle 238°, no related flare observable; large bright [Sacramento Peak]				
				Flare (point 1) 19:08-19:32, S21 W90) [U.S.Naval Laboratory])	4189	94-118 W ~98 W	12	~10-92 (before the flare)
8	7.XI	19:45-20:00	1+	Brilliance; 19:40, S25 E90 [Sacramento Peak]				
				Surge (point 2) 19:41-? position angle 110° [Juancaio])				
				Active prominence (point 3) 19:42-? position angle 115°, large [Sacramento Peak])	4237	84-100E ~96 E	3	~10
9	25.XII 1957	16:45-17:15	1+	Brilliance, 16:32, N20 W70 [Sacramento Peak]	4314	65-82W	12	
				Surge (point 2) 15:10-21:40, position angle 250°, no related flare observable; continuous [Sacramento Peak]	4313?	78-94W	-	~ 10
10	2.II 1958	17:15-17:30	1	Brilliance; 16:40, S12 E74 [Sacramento Peak]	4402	68-80E	-	
				Surge (point 1) 17:12-? position angle 250°, no related flare visible [Juancaio]	4382	90-104W	1 (type IV flash-up)	~10-21
11	2.VIII	18:45-20:45	2+	Surge (point 2) 18:40-18:47, S13 W90, possibly "flare spray" [Climax])				
				Surge (point 2) 18:47-19:03 S 14 W90)				
				Surge (point 1) 20:39-21:17 S 13 W90) [Climax])	4659	79-120W ~103W	12	~ 10-108 ~ 18
				Surge (point 2) 21:44-22:34 S13 W90) [Climax])				

12	20.VIII	20:45-21:15	1	Brilliance; 21:04, N 06 E81 [Sacramento Peak])				
				Active prominence (point 1), <21:6->21:25, position angle 085°; connected with brilliance; thin, very bright, not very active) [Sacramento Peak]	4715	72E	-	
13	10.IX 1958	13:30-14:00	1	Brilliance, 13:44 E, N14 E90 [Sacramento Peak])				
				Surge (point 1) 13:48-15:15 N13 E90, length 1',2 [Anacapri])	4756	85-109E	-	~ 10-40
14	10.X	02:00-03:00	2-	Active prominence (point 2) 02:10-05:45, S10 E90 high activity [Codaicanal])	4826?	130-140E	9	
15	13.X	06:30	1-	Active prominence (point 2) 06:17-08:05, S 04 E95, no related flare visible; average activity [Tashkent]	4826	94-104E	9	~ 10-21
16	20.XII	11:30-11:45	1	Active prominence (point 2) 11:28-? S 13 E90, highly active, "sprays" of great magnitude [Capetown]	4934	88-112E	6	~10-55
17	3.I 1959	02:00-02:45	1-	Active prominence (point 2) 02:10-09:00, N 10 E90 [Codaicanal]	?			
18	4.I	03:15-03:45	1+	Surge (point 2) 03:22-04:20 S 15 W 90 [Codaicanal]	4334	93-102W ~ 98W	6	~10-15
19	5.III	05:30-06:30	1+	Surge (point 1) 06:15-06:28, N20 W90 [Codaicanal]	5026	86-100W	3	~10
20	6.III	00:45-01:15	1-	Active prominence (point 1) 23:38-01:26, S 19 W90 [Sydney]	?			
21	10.III	05:30-06:15	1+	Surge (point 1), 04:37-04:49, N 18) E90, without a flare [Sydney])	5052	96-104E	-	~10-21
				Surge (point 1), 06:00-06:40, N18 E90 [Codaicanal])				

22	6.V	14:45-15:30		Brilliance, 14:30, N 25 E73 [Mac Mas]				
				Surge (point 2+), 15:00-15:45, position angle 060° connected with brilliance, great, bright [Sacramento Peak]	5147?	63-81 E	5	
				Surge (point 1), 14:49-15:13, N 25 E 90, length 1', 8 [Anacapri]	5148?	97-116E ~ 110E	10	~10-78
23	9.VI 1959	16:45-20:00	3	Surge (point 1), 17:09-17:22, N 18 E 90, no related flare visible [Ottawa]				
				Active prominence (point 3), <17:20-24:00, N 15 E 90, very bright, not connected with flare [Climax]				
				Brilliance, 17:32 E, N 18 E 90 [Sacramento Peak]	5204	98-108E 101E	10	~10-36 (before the flare)
				Surge (point 1+) <17:32->23:46, position angle (072), connected with brilliance, frequent, moderate, bright [Sacramento Peak]				
				Active prominence (point 3); <17:32->23:46, position angle 072°, very bright, complex, high [Sacramento Peak]				
				Flare (point 2), 18:00-19:10, N 17 E 90 [Honolulu]				
24	1.VII	18:00-19:15	1+	Brilliance; 17:30 E, N 11 W90 [Mac Mas]				
				Surge (point 1), 14:02-23:42, position angle 281°, connected with brilliance, small, bright, continous [Sacramento Peak]	?			
				Surge (point 1-), 17:45-18:15, N 07 W 90, altitude < 0.05 R [Lockheed]				

25	22.VIII 1959	01:00-02:00	1+	Brilliance, 01:02, S 10 E90 [Lockheed])			
				Surge (point 1), 01:10-02:00 S 10 [Honolulu])	5340	86-93F	3